

CALIFORNIA DIVISION OF MINES AND GEOLOGY

Fault Evaluation Report FER-42

November 30, 1977

1. Name of faults: Norwalk and El Modeno faults.

2. Location of faults: The Norwalk fault occurs within the La Habra<sup>ca</sup> and Anaheim 7½' quadrangles, Orange County. The El Modeno fault occurs within the Orange 7½' quadrangle, Orange County (figure 1).

3. Reason for evaluation:

These faults are located within the 1977 study area of the 10-year program for fault evaluation. Also, Holocene activity has been ascribed to each of these faults by one or more workers.

4. List of references:

California Department of Water Resources, 1967, Progress report on ground water geology of the coastal plain of Orange County:

California Department of Water Resources, 139 pages.

(Not available in San Francisco District office.)

Jennings, C.W., 1975, Fault map of California with locations of volcanoes, thermal springs and thermal wells: California Division of Mines and Geology, California Geologic Data Map Series, Map no. 1. Scale 1:750,000.

Lamar, K.L., 1972, Microseismicity and recent tectonic activity in Whittier fault area, California: Earth Science Research Corporation Final Technical Report for U.S. Geological Survey, National Center for Earthquake Research, 33 p. Map scale 1:48,000.

(One microseismic event occurred on the Norwalk fault on January 11, 1972.)

Miller, R.V., S.S. Tan, R.H. Chapman, and G.W. Chase, 1977, Recency of faulting of major faults in Orange County, California: California Division of Mines and Geology, Open File Report (in review). Map scale 1:24,000.

(This is the most recent study that deals with the question of recency of activity along the Norwalk and El Modeno faults.)

Morton, P.L., R.V. Miller, J.R. Evans, 1976, Environmental Geology of Orange County, California: California Division of Mines and Geology open file report (in review). Map scale 1:48,000.

OFR 78-8LA

(This is the second most recent study that deals with the question of recency of activity along the Norwalk and El Modeno faults.)

Real, C.R., D.L. Parke, and T.R. Topozada, 1977, Magnetic tape catalog of California earthquakes, 1900-1974: California Division of Mines and Geology.

Richter, C.F., 1958, Elementary seismology: W.H. Freeman and Company, San Francisco. Map scale 1:700,000.

(He attributes the "Whittier" earthquake of 1929 to the Norwalk fault.)

Richter, C.F., 1942, Earthquake near Whittier, California, January 29, 1941: Bulletin of the Seismological Society of America, v. 32, no. 1, p. 3.

Schoellhamer, J.E., D.M. Kinney, R.F. Yerkes, and J.G. Vedder, 1954, Geologic map of the northern Santa Ana Mountains, Orange and Riverside Counties, California: U.S. Geological Survey Oil and Gas Investigations Map OM 154.

(This map shows the El Modeno fault.)

Woodford, A.O., J.E. Schoellhamer, J.G. Vedder, and R.F. Yerkes, 1954, Geology of the Los Angeles Basin, in Jahns, R.H., editor, Geology of southern California: California Division of Mines and Geology Bulletin 170, p. 65-81. Map scale 1:95,000.

(Their plate 1 shows the Norwalk and El Modeno faults, and plate 1A has a cross section across the Norwalk fault.)

- ✓ Yerkes, R.F., 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geological Survey Professional Paper 420-C, 63 p. Map scale 1:24,000.

##### 5. Summary of available data:

###### Norwalk fault

Morton and others (1976, p. 311) give an excellent, brief, description of this fault:

The Norwalk fault is known only from subsurface oil well and water well data. It has been plotted trending west-northwest from Norwalk in Los Angeles County to the south edge of the West Coyote Hills, a total distance of about six miles. The "Whittier" earthquake of 1929 has been attributed by Charles Richter to the Norwalk fault, and as a result of this statement, the feature has received much attention as an active fault (Richter, 1958, p. 43). The youngest rock unit of record to be displaced by the fault is the San Pedro Formation (Yerkes, 1972, plate 2) of early Pleistocene age (750,000 years B.P.). Lamar (1972) has shown little evidence for active seismicity along the fault in his microseismicity study, and very few epicenters recorded since 1934 plot near the subsurface trace of the fault. Even the location as plotted at the south edge of the Coyote Hills is subject to question. Yerkes (1972, p. C31) infers that the fault swings northerly where it projects into Orange County, but his map of the same area shows a fault lying along the south edge of the West Coyote Hills. Previous locations of the fault along Malvern Avenue were based on the presumed geomorphic expression of an eroded fault scarp, but as noted by Yerkes this can be attributed also to stream cutting caused by crowding of the local drainage northward by alluvium built up by an older Santa Ana River drainage course. That this process would result in such remarkable linearity, however, seems unlikely without the additional factor of an existing "scarp" to influence the straight front of the hills. It is noteworthy that no other reach of the Santa Ana River has resulted in a similar linear feature.

Ground water data indicate a ground water barrier along the southern edge of the Coyote Hills but this plots about 4,000 feet north of Malvern Avenue (California Department of Water Resources, 1967, p. 29, plate 3). A northwest-trending fault in the La Habra Formation is apparent in the vicinity southeast of the Los Coyotes Country Club house about 1,000 feet south of the ground water barrier. No faulting is apparent in well-exposed La Habra Formation at Malvern Avenue to 500 feet northward. A north-south seismic profile through the middle of the West Coyote Hills done for petroleum exploration shows evidence at depth for the Norwalk fault that projects to the surface about 1,000 feet south of Malvern Avenue near Bastanchury Road.

In summary, the data available bearing on the location and recency of the Norwalk fault are inconclusive. However, because of the implications of recent faulting and the consequences of ignoring this possibility, it is prudent to either investigate the problem more fully or to require mitigating construction measures until such time as the facts become known.

Morton and others (1976) do not show the 'northwest trending fault in the La Habra Formation' on their map (their plate 1). The La Habra Formation is of middle Pleistocene age.

Other writers are also concerned about the problem of locating the Norwalk fault at the surface. Yerkes (1972, p. C31) writes:

Thus, although the epicenters of the 'Whittier' earthquake can be associated spatially with a buried fault, the only possible surface expression of faulting in this area (the West Coyote "scarp") that can be associated with the Norwalk fault of Richter cannot be correlated with any recognized subsurface feature.

Miller and others (1977) state:

The trace of the fault as shown on plate 3 was generally located by two deep seismic, north-south, profiles previously generated by oil companies. One profile was taken along Harbor Boulevard and the other east of and parallel to Brookhurst Street. Both profiles show evidence for a major fault dipping to the north, lying south of the West Coyote Hills. The break is well-defined below a depth of 2,000 feet (600 m) where it displaces late Pleistocene and older sediments, but becomes difficult to trace in the records above that. The proposed trace of the Norwalk fault on plate 2 is not aligned with the edge of the alluvial terrace south of the West Coyote Hills as it has been in previous reports (J.E. Schoellhamer, et al., 1954, and R.F. Yerkes, 1972).

The locations of the fault, as shown in the various references, are compiled on figure 3 of this FER.

One other reference (Woodford and others, 1954, plate 1A) shows the Norwalk fault in cross section. Their cross section DE shows the fault extending to within 200 m of the surface, cutting lower Pleistocene La Habra Formation strata, but not cutting upper Pleistocene alluvial "terrace" strata. They show the fault dipping about  $80^{\circ}$  north, and queried lower Pleistocene and upper Pliocene contacts are shown to be vertically displaced about 1,000 feet, northern side upthrown. The approximate alignment of that cross section is shown on Figure 4b.

Regarding the eastward continuation of the fault, Woodford and others (1954, plate 1) extend the Norwalk fault eastward to connect with the El Modeno fault. No other reference shows or describes such a connection. Miller and others (1977) state, "The eastern extent of the Norwalk fault is still in question as no subsurface data were obtained east of Harbor Boulevard; however, a connection with the El Modeno fault is doubtful ..."

Regarding seismicity, Richter (1942 and 1958) ascribes two events to the Norwalk fault: a 4.7 magnitude event in 1929 and a 4.0 magnitude event in 1941. The microseismicity study by Lamar (1972) recorded one microearthquake with a hypocenter on the Norwalk fault out of a total of 31 events that he recorded in the area. Epicenter data from Real and others<sup>(1977)</sup> are shown on figures 2a and 2b. There appears to be no correlation between the distribution of events and the location of the Norwalk fault.

### El Modeno fault

Morton and others (1976, p. 307) give an excellent, brief, description of this fault:

The El Modeno fault as shown on the geologic map (plate 1) extends from the Santa Ana River eastward to Santiago Creek in Villa Park. Then it swings more southerly toward Cowan Heights to Peters Canyon wash. The fault trace segments lie separated by short expanses of alluvial material and their connection as shown on plate 1 is a matter of interpretation. Among the youngest sediments cut by the fault are nonmarine terrace deposits of Pleistocene age at Cerro Villa Heights. A trench placed in that area by a developer exposed the faulted base of the terrace deposits. At another trench site examined by the Division of Mines and Geology in this study, alluvium of Holocene age was apparently disrupted by the fault where it traverses Santiago Creek. Exposures in the trenches showed alluvium of Santiago Creek juxtaposed against clayey gouge and Sespe Formation (figure 5.1G). Alluvium in one trench contained bedding as steep as  $53^{\circ}$ , lying nearly parallel with the strike and dip of the fault zone.

Other evidence suggesting Holocene movement along the fault is an anomalous steep ground water gradient at the projection of the fault across the Santa Ana River alluvium near Olive (California Department of Water Resources, 1967, p. 29, 30. Contours drawn on the base of the most recent alluvium, as determined by interpretation of well drillers logs in the same area, likewise show a steep decline southward across the fault projection (figure 5.1H); however, this condition is easily explained by a subsurface extension of the erosional surface of Burrue! Ridge. What is not easily explained is the buried closed depression just northwest of the steep decline.

Some geologic maps have shown the El Modeno fault connected with the Norwalk fault which trends west-northwest from the West Coyote Hills to Norwalk (Jahns, 1954). The present study has found no basis for this relationship and will, therefore, consider each fault separately.

P.K. Morton (oral communication, 12-20-77) provided more specific information about the trenches and the character of the El Modeno fault. He gave the location of the trench "by a developer"; it is shown on figure 4c and labeled "developer's trench." What he above refers to as "another trench site" where the fault crosses Santiago Creek, was actually two trenches, the same as trenches 25 and 26 discussed by Miller and others (1977) (shown as figures 3a and 3b of this report). In the oral

discussion, Morton still maintained that the unit "Qal" in the trench logs is of Holocene age and that it was clearly observed to be faulted in trench 26. He said, however, that there are problems in relation to this observation. The projected continuation of the fault could not be found in the canyon wall, several hundred feet to the southeast. The alluvium of the canyon wall, mapped as terrace deposits, is presumably older than the "Holocene" alluvium that is faulted where the trench exposures were made. Furthermore, he says, the terrace surface, long since abandoned to further deposition, shows no scarps or other evidence of faulting. He says he ~~do~~<sup>d</sup>oes not know how to reconcile this observation with the trench observations, except that the Canyon Wall exposures are poor and the fault may in fact be there.

Miller and others (1977) give a similar description of the El Modeno fault. They add (p. 31), "Generally the middle Miocene Topanga Fm. has been downdropped on the west and southwest adjacent to late Eocene to early Miocene rocks of the Vaqueros and Sespe Formations, undifferentiated, on the east and northeast."

Miller and others (1977) give additional discussion of the two trenches near Santiago Creek:

Two trench sites were excavated by the Division of Mines and Geology; one in 1973 (T25 and 26, plate 3) and one during this investigation (T27, plate 3). Trenches T25 and T26 (see figure 25 and 26) exposed alluvium of probable Holocene age which had been displaced and deformed by the El Modeno fault. In the Santiago Creek channel a few feet south of trench site T26, alluvium exposed along the north bank can be observed dipping steeply to the west. Trench T27 (see figure 27) two miles (3.2 km) south of Santiago Creek, showed an apparently undisturbed, 2 to 3 foot thick (30-90 cm) soil layer overlying the fault zone.

The trench logs, figures 25, 26, and 27 in Miller and others (1977), are reproduced in this report as figures 3a, 3b, and 3c. Miller (oral communication, 11-29-77) said that they had no hard evidence that the faulted material was of Holocene age. He said that where this sort of qualitative judgement had to be made, he usually decided in favor of public safety -- that is, in this case, he chose to call it Holocene rather than late Pleistocene.

Regarding the continuity of the El Modeno fault, P.K. Morton (personal communication, 12-20-77) admitted that it was somewhat speculative. He said there may be no through-running fault, or fault zone, as mapped by himself and by other earlier workers.

No significant earthquakes have been attributed to the El Modeno fault. However, Reel and others (1977) show four minor seismic events on or just north of the western end of the fault (see figures 2a and 2b of this report). These events, 2 of "A" location quality and 2 of "B" quality, could have occurred on the El Modeno fault or along the Peralta thrust fault or related small faults that lie within a few kilometers to the north of the western part of the El Modeno fault. Morton and others (1976, p. 312) discuss these smaller faults:

An unnamed fault that may be structurally related to the El Modeno fault lies about one mile north of it on Burrue! Ridge in Villa Park. It is an east-trending north-dipping thrust fault which has thrust the La Vida Member of the Puente Formation up over nonmarine terrace gravels. Several smaller related nearby faults lying just south of the thrust fault were mapped by a private consulting firm in a study for the Southern California Edison Company in 1971. This investigation revealed the slope wash and coluvial materials of Holocene age were displaced by some of these faults. The fact that these are regionally insignificant faults suggests that this displacement may have resulted from movement on a larger, nearby, and more regional structure. It is reasonable to speculate that it may

have been due to Holocene movement on either the El Modeno fault, the closest large structure, or even the Whittier fault, which lies some  $4\frac{1}{2}$  miles to the north.

P.K. Morton (personal communication, 12-20-77) said that the report "by a private consulting firm" is still of a confidential nature, and he could not give us additional information about it at this time. He said that the "Several smaller related nearby faults lying just south of the thrust fault" were not shown on his map, and, furthermore, he had not personally seen any of these features; the statement that "materials of Holocene age" were involved in faulting is purely the opinion of the consultant.

Other faults:

Historic ground rupture occurred along a small, unnamed fault in the northern part of the West Coyote Hills, about 3 km north of the Norwalk fault. Yerkes (1972, p. C31) describes the event:

About October 1, 1968, surface rupture occurred along a north-trending zone about 1,000 feet long located near the bottom of a small north-trending canyon at the north margin of the West Coyote oil field (near the  $W\frac{1}{4}$  cor. sec. 17, T. 3 S., R. 10 W.; plate 1). The rupture was first observed on October 9 and was mapped on October 18; it was reexamined on November 21, 1968, when no evidence of renewed movement was found. The ruptures did not follow any previously mapped fault, but may represent a north-ward extension of such a fault. The zone, which was 5-38 feet wide, consisted of a series of en echelon cracks up to 15 feet long; the zone trended northward, whereas individual cracks trended N. 20-25° W. and dipped about 55° E. Dip slip was 1-3 inches, displacement was up on the east, and left-lateral slip of up to 2 inches was locally present. The zone occupied the stream bottom in large part; however, where the zone crossed an east-sloping spur ridge, displacement of the downslope block was relatively up. Two seismic events that might be related to the faulting were recorded by the Seismological Laboratory, California Institute of Technology (J.M. Nordquist, personal communication, October 1968):

1. September 23, 1968, 1715 G.C.T. at 33° 56' N. and 117° 33' W., magnitude 2.6 (?). (These coordinates plot about 23 miles east of the fault.)
2. October 3, 1968, 1745 G.C.T. at 34° 04' N. and 117° 47' W., magnitude 2.2.  
(These coordinates plot about 15 miles northeast of the fault.)

R.F. Yerkes (personal communication, 1-9-78) added that the fault was of the reverse type. He said that the oil field underlying this area was undergoing high pressure injection of water at the time the ground breakage occurred, and that this may have caused the fault movement. He said he was unaware of any reactivation of faulting in this area subsequent to October 1968.

*Large amount of water injected into the oil field at the time of the rupture.*

6. Interpretation of aerial photography: None.
7. Field observations: None.

## 8. Conclusions:

There is good reason to believe, on the basis of seismic evidence, that the Norwalk fault, or some fault within 2 km of what is called the Norwalk fault, has been historically active at depth. The problem is, the Norwalk fault is not well-defined, either in the subsurface or the surface. There is no direct evidence (such as actual exposures of faulted rock) of a surface trace.

The El Modeno fault, is, at least in part, sufficiently well-defined for zoning purposes. However, this fault is a borderline case; to again quote Morton and others (1976, p. 307), "The fault trace segments lie separated by short expanses of alluvial matter and their connection, plate 1 is a matter of interpretation." The term 'short expanses' seems to be intrinsically contradictory. His plate 1 shows 5 such 'short expanses' greater than one kilometer in length. It appears, that for the purposes of the Fault Evaluation Project, the El Modeno fault is not sufficiently active.

The short fault in the northern part of the West Coyote Hills clearly meets our criteria for being sufficiently active and well-defined. But, it is very short (only about 300 m long) and it is not clear as to what actually caused the ground breakage.

9. Recommendations:

I recommend against zoning the Norwalk fault because no one has ever found it at the surface. I slightly favor not zoning the El Modeno fault because it is not that well-defined, and I suspect that the evidence for Holocene movement is weak. I do not recommend zoning the smaller faults to the north of the western part of the El Modeno fault. I recommend further investigation of the small, historically active fault in the northern part of the West Coyote Hills. The fault should be re-examined on the ground. The oil field operators should be contacted to see if they can provide any information about the cause of the faulting.

10. Investigating geologist's name and date:

*Drew P. Smith*

DREW P. SMITH  
Geologist  
November 30, 1977

I concur with the recommendations. The unnamed active fault in West Coyote Hills should be field checked for additional offset. The operators contacted, Re this, DOG statistics show that the oil & assoc. water production from the W. Coyote field probably caused subsidence or ~~the~~ the huge amts of water injected may have caused rebound this. Water production greatly exceeded 1976 and water production greatly exceeded 1976. Since reserves are only 13,000,000 bbls, then the field is nearing depletion (and fault movement may have stabilized). EO Norwalk field should be field checked along Santiago Cr. for evidence of recent faulting (e.g. terrace deposits near T25 & T26). I suspect that the faulted alluv. is pre-Holocene.  
EHA  
11/19/77

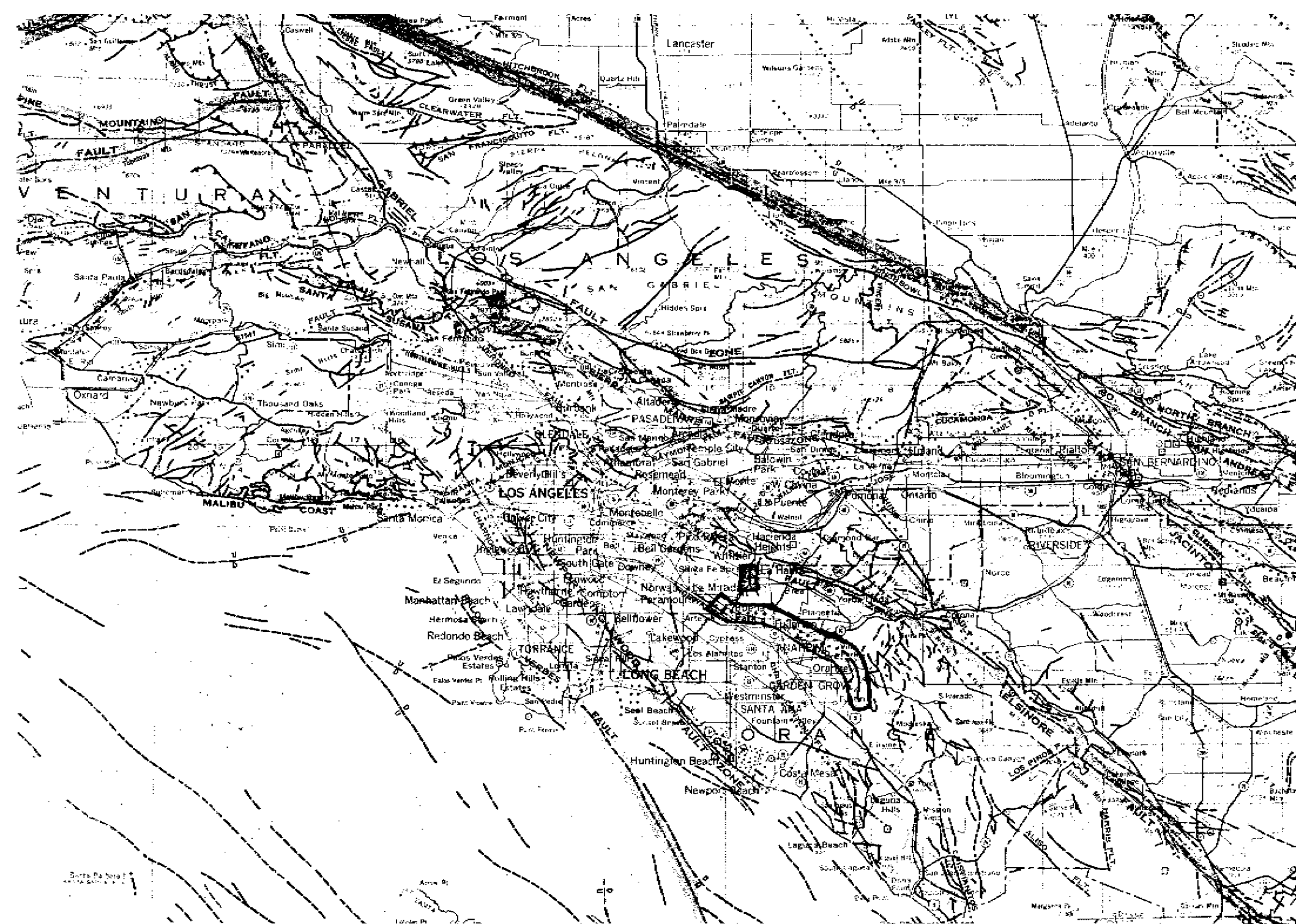


Figure 1. Index map showing locations of the Norwalk and El Modeno faults.

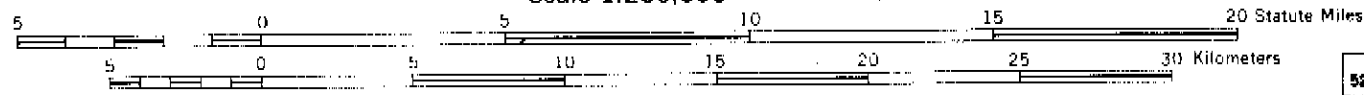
FER 42

Map is modified from Jennings (1975).

# EPICENTERS IN THE L. A. AREA, ~~A~~ QUALITY

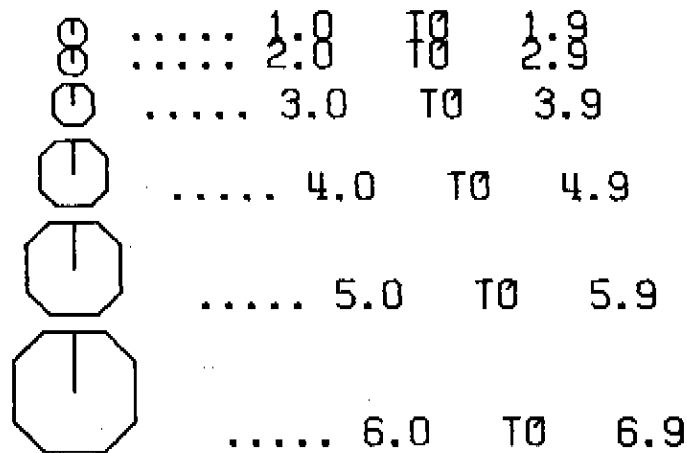
TRANSVERSE MERCATOR PROJECTION

Scale 1:250,000



52

MAGNITUDE



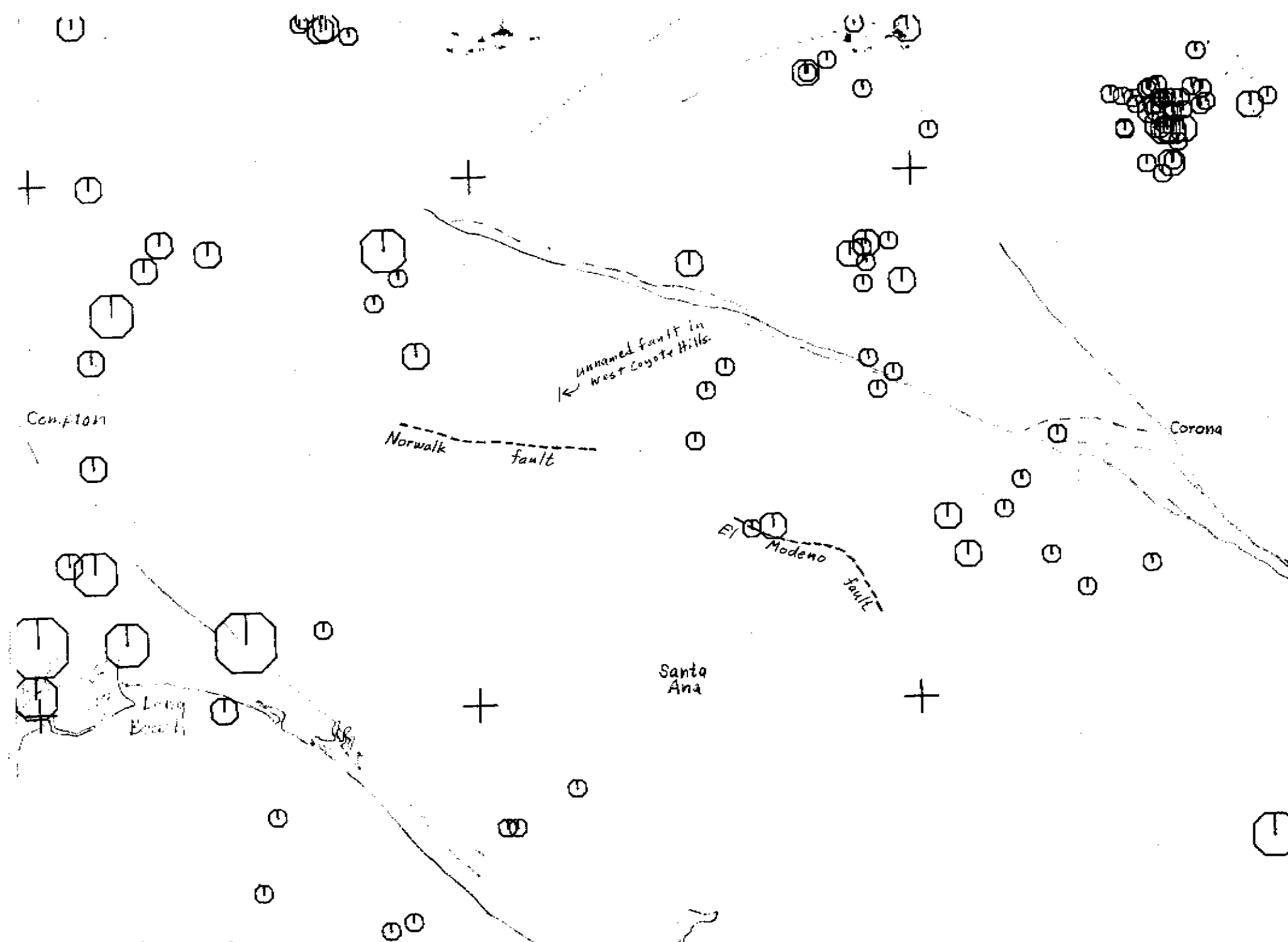
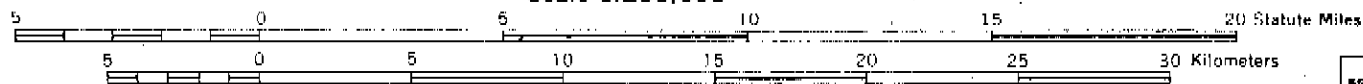


Figure 2a. Regional seismicity of the southeastern Los Angeles Basin area. "A" quality data  
 FER 42 from Real and others (1977).

# EPICENTERS IN THE L. A. AREA, ~~B~~ QUALITY

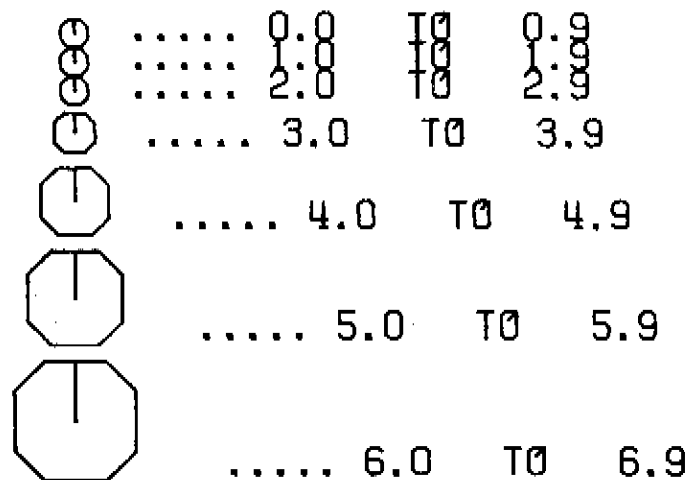
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Scale 1:250,000



MAGNITUDE

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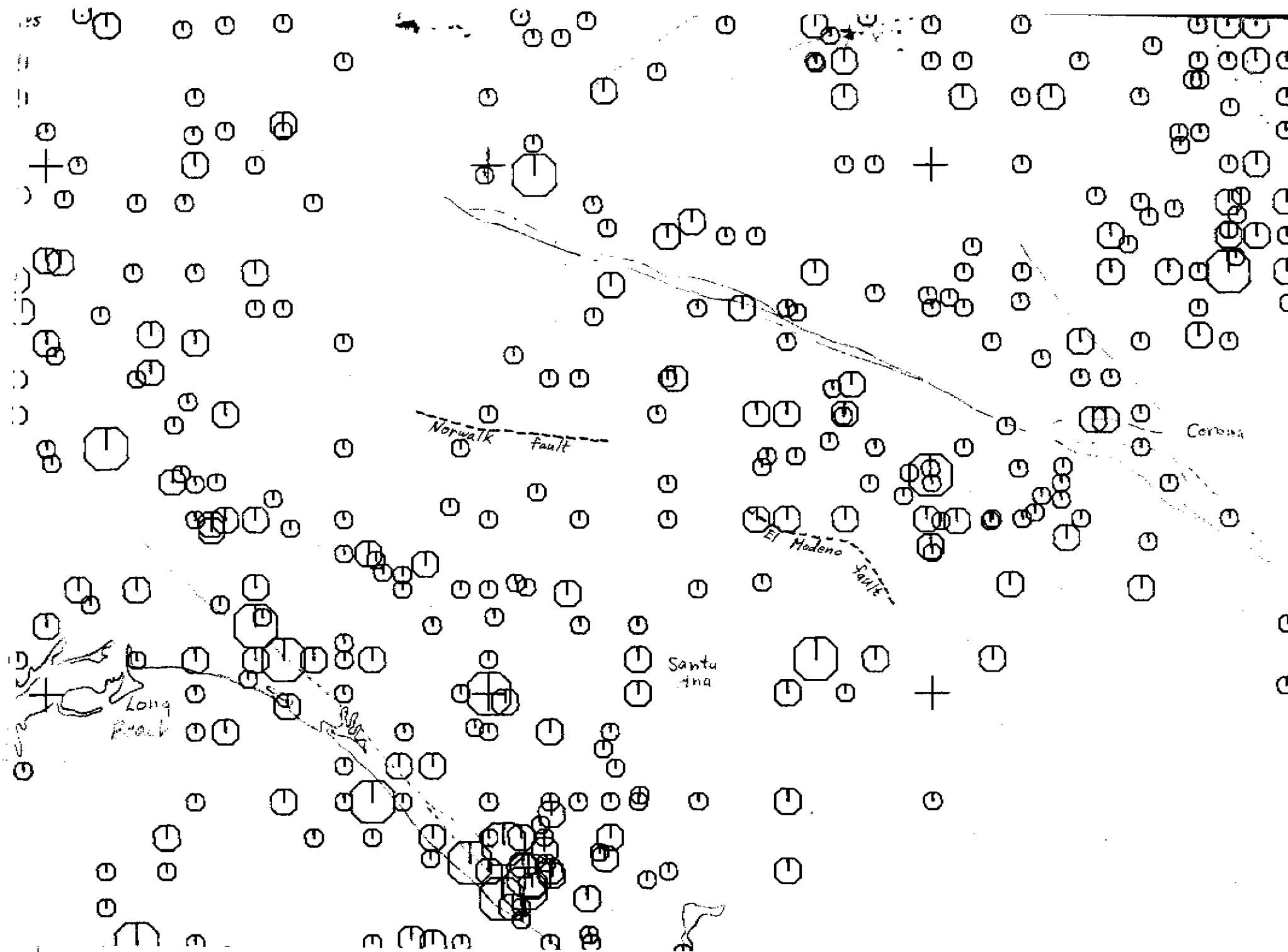


Figure 2b. Regional seismicity of the southeastern Los Angeles Basin area. "B" quality data  
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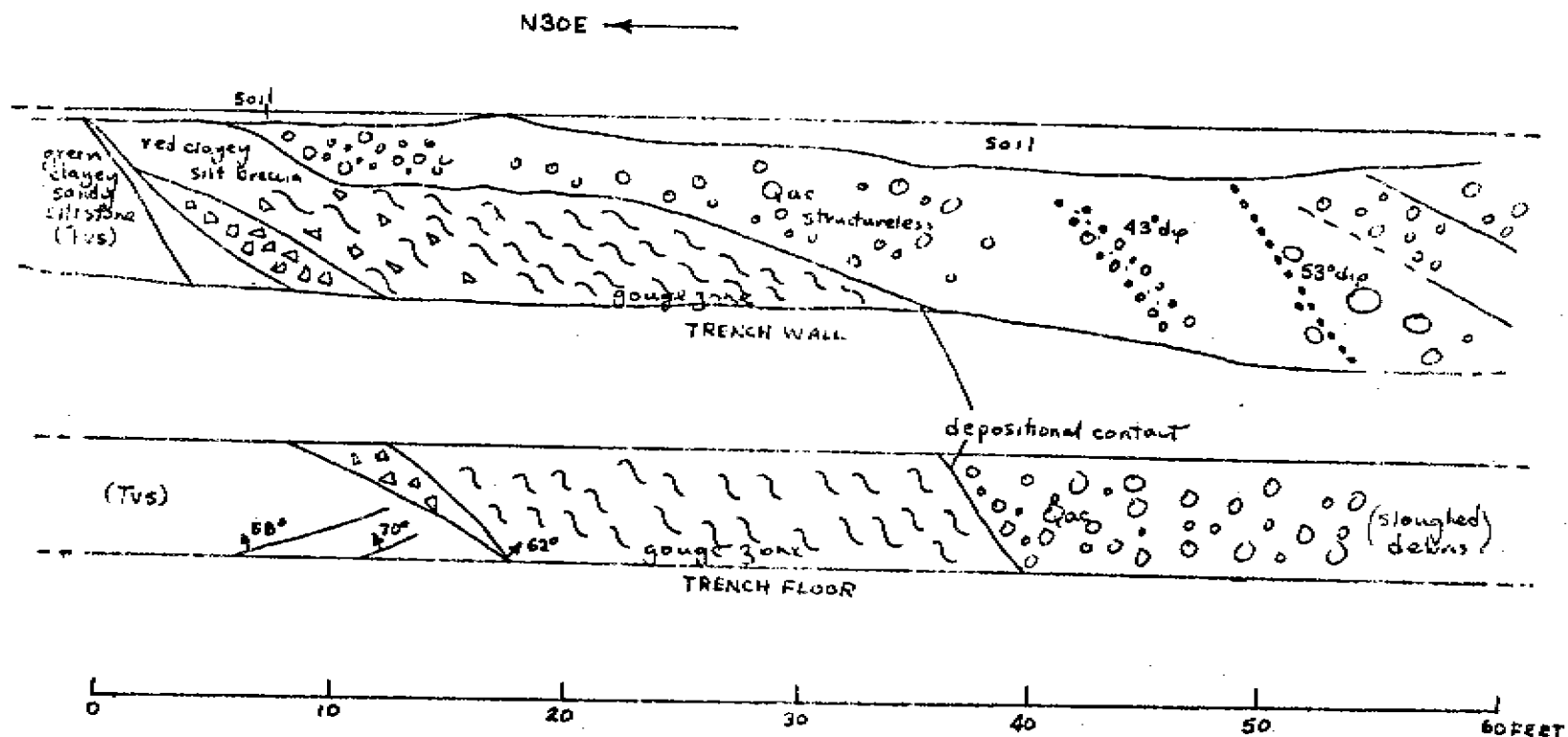


Figure 25 TRENCH EXPOSING EL MODENO FAULT NEAR SANTIAGO CREEK

Figure 3a. Reproduction of trench log T25 (figure 25 of Miller and others, 1977).

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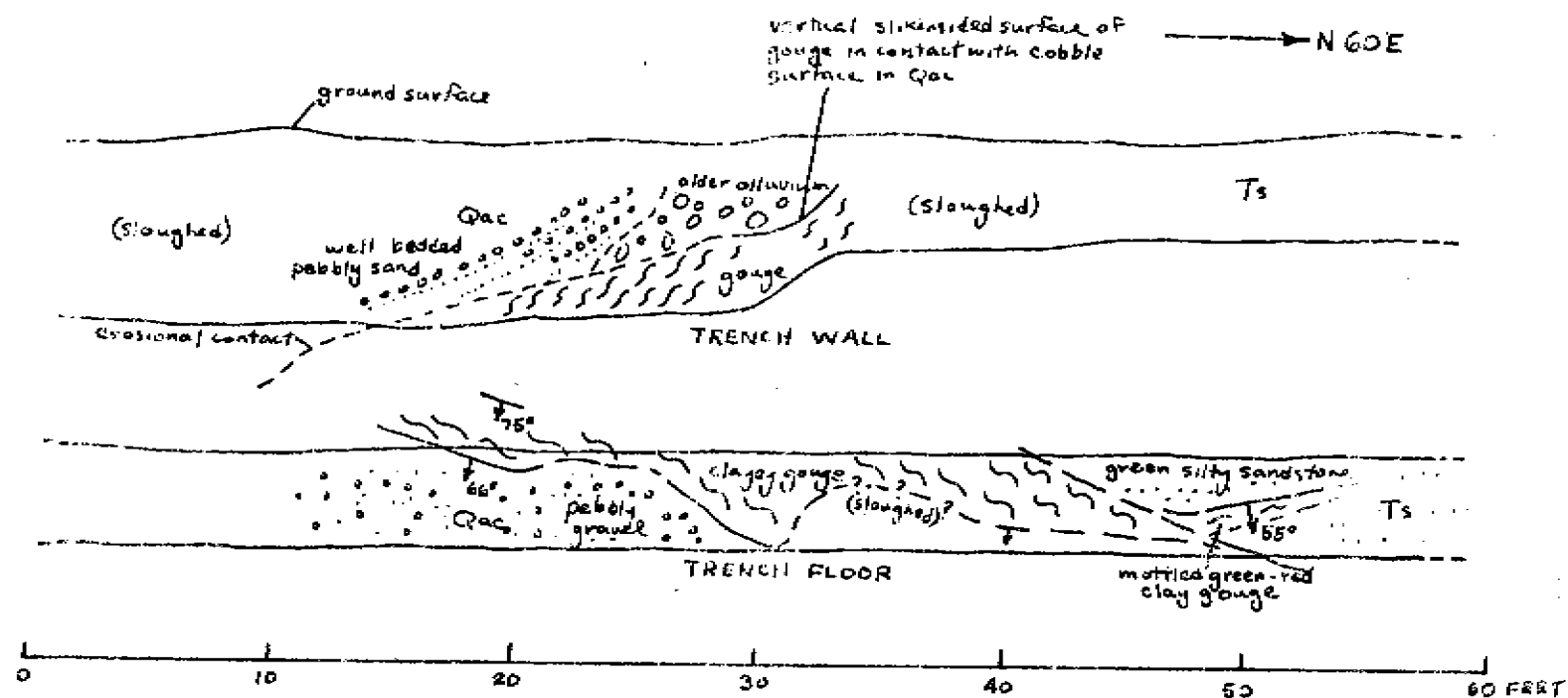


Figure 26 TRENCH EXPOSING EL MODENO FAULT NEAR SANTIAGO CREEK

Figure 3b. Reproduction of trench log T26 (figure 26 of Miller and others, 1977).

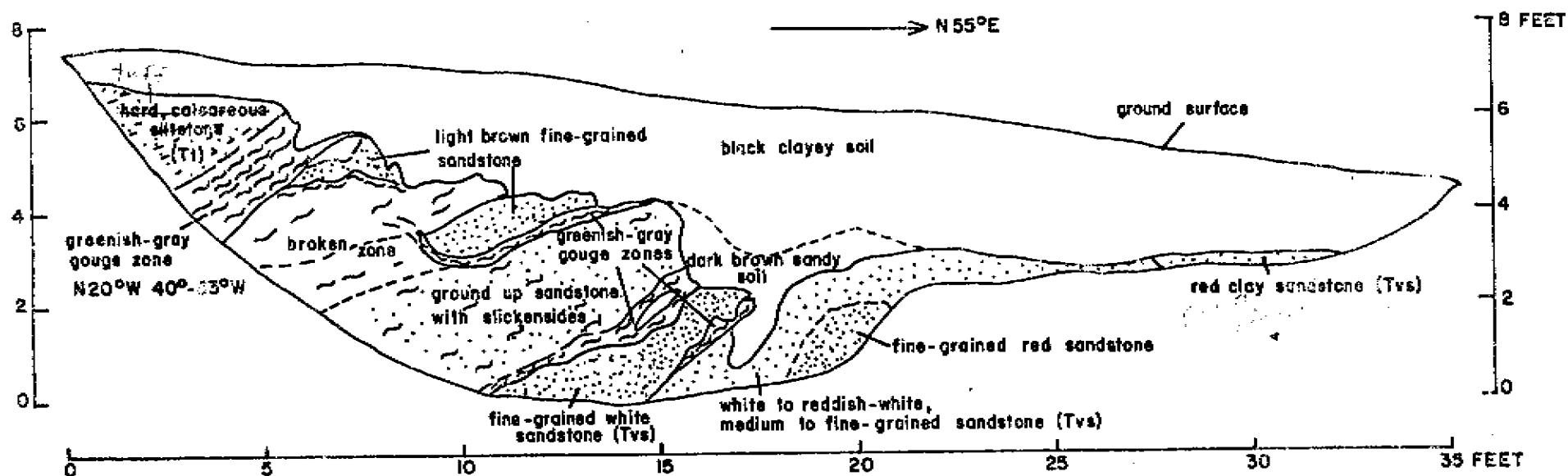


Figure 27 TRENCH EXPOSING EL MODENO FAULT WEST OF NEWPORT BOULEVARD

Figure 3c. Reproduction of trench log T27 (figure 27 of Miller and others, 1977).

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